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Research

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Understanding the Effect of High-Cut Shoes, Running Shoes and Prophylactic Supports on Ankle Stability When Performing a "V"-Cut Movement

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ABSTRACT

Ankle inversion injury is extremely common in basketball, whereby rearfoot inversion and ankle plantar flexion is greater in those with injury. The current study analysed the response of recreational basketball players to three different footwear conditions; high-cut basketball shoe, low-cut running shoe and low-cut running shoe with ankle brace. Ten recreational male basketball players performed 45° "v"-cut movements at an approach speed of 4.5m/s. Dependent variables included peak initial rearfoot inversion and ankle plantar flexion. Peak impact force was also measured due to the potential difference in cushioning provided by the footwear. Repeated measures ANOVA were used to compare dependent variables with statistical significance accepted at $p < 0.05$. Results indicated that there were no significant difference for plantar-flexion ($F = 2.94$, $p > 0.05$; Partial $\eta^2 = 0.25$) and impact force ($F = 3.189$, $p > 0.05$, Partial $\eta^2 = 0.26$).On the other hand, comparison of peak initial rearfoot inversion showed that there were significant differences between footwear conditions. Pairwise comparisons with Bonferroni adjustments showed significantly larger peak initial rearfoot inversion values for the high-cut basketball shoe compared to both the low-cut running shoe ($p = 0.001$) and the low-cut running shoe with brace condition ($p = 0.001$). Findings indicate the potential for using low-cut running shoes for recreational basketball without an increased injury risk.

KEYWORDS: "V"-cut; Ankle inversion; Ankle sprains; High-cut and low-cut shoes

INTRODUCTION

Basketball is a fast paced, highly intermittent sport.[1,2] During the game, players perform a wide variety of high intensity and multi-directional movements, changing direction on average every 2 seconds.[1,3] These characteristics contribute to players exhibiting a high frequency of injury compared to other team sports,[4] particularly at the lateral ankle,[5,6] which result from performing movements such as a "v-cut".[7-10] The occurrence of an initial injury then acts as a predisposing factor for recurrent injuries as well as chronic ankle joint instability and degeneration.[11,12]

The lateral ligaments work alongside the peroneal muscles to control the level of lateral movement experienced by the ankle.[13] When the loads are excessive, there is a greater chance of ankle sprain or tear occurring.[8,14,15] Baumhauer et al.[16] found that 85% of all ankle injuries are caused by excessive rearfoot inversion, caused by sudden lateral forces which are sufficient to compromise the joint integrity. This excessive force is often evident during the initial contact of the foot with the ground, since continuing forward momentum of the body can

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cause an increase in the rearfoot inversion experienced during this early stage of ground contact. This sudden change in lateral force can also relate to many different factors, which include the design of the footwear, playing surface-footwear traction, speed of the movement and contact with opposition players. The degree of rearfoot inversion movement can also be influenced by level of plantar flexion the ankle is in; a greater range of rearfoot inversion movement is possible in plantar flexed compared to a dorsi-flexed position.[17]

To limit excessive lateral movement about the ankle, traditional basketball shoes are designed with high-cut ankle supports acting to limit the ankle movement.[18,19] Manufacturers however, have developed new designed shoes that are medium and low cut which are chosen by professional and semi-professional players based on individual preference relating to their playing position or stature.[20] Lowe[21] recommends changing footwear once a month, yet basketball shoes are expensive and not everyone can afford to by a pair.[22] Consequently, recreational players will often utilise their own low-cut running shoe, which offers improved cushioning compared to court shoes such as those worn in basketball,[8] but which are thought to have greater instability since the running shoe midsoles allows greater compression of the lateral edge, increasing the lever arm between the external force and the ankle joint; this increases the external torque and introduces greater instability.[8]

If regular running shoes are to be used, the addition of ankle bracing through prophylactic supports may be beneficial since the device has been shown to reduce the risk of injury.[11,12,23] Further still, although the cut of the ankle is thought to be a risk factor for injury, there is still uncertainty concerning the beneficial effects of shoe collar height for ankle sprain prevention.[9] Gottschalk & Pepple,[24] found that high-cut shoes did not show greater prevention of ankle sprains compared to low-cut shoes especially for those who had no history of ankle sprains. Similarly, Rovere, Clarke, Yates and Burley[25] demonstrated that in comparison to low-cut basketball shoes, high-cut shoes were not more effective in reducing the incidence of ankle injury and further still fewest injuries were observed with low-cut shoes coupled with laced ankle stabilizers. Curtis, Laudner, McLoda and McCaw[26] also found that additional cushioning through midsole columns did not increase the risk of injury. As such, it may be questionable that cushioned footwear does cause an increase in rearfoot movement and greater risk of injury.

The aim of this study is to investigate the hypothesis that low-cut running shoes combined with an ankle brace will result in significantly less peak initial rearfoot inversion and plantar flexion than a high-cut basketball shoe or low-cut running shoe only condition. There will also be reduced peak initial rearfoot inversion and plantar flexion with the high-cut basketball shoe compared to the low-cut running shoe only condition. Finally, it is hypothesized that the greater cushioning will be provided by the low-cut running shoe with and without the ankle bracing compared to the high-cut basketball shoe.

METHODS

Ten recreational male basketball players (22.0 ± 4.0 years; 177.7 ± 4.9 cm; 79.3 ± 11.3 kg) took part in the study. Ethical approval was obtained for the study via the Aberystwyth University's ethics procedure. Participation in the study was completely voluntary and all participants were free to withdraw at any time. Participants were excluded from the study if they had experienced an injury within 6 weeks prior to the start of data collection. An injury was defined as a problem that occurred as a result of playing basketball or similar sport, that required medical attention by a certified trainer or physician and resulted in restricted participation for a period of 2 or more days beyond the day the injury occurred.[27,28]

Participants performed a sideways 45º "v-cut" movement which can be described as a lateral movement performed on a single leg support, where the load bearing leg propels the body towards the contralateral direction.[7] "V"-cut movements were performed under three conditions; high-cut basketball shoe, low-cut running shoe and low-cut running shoe with prophylactic ankle brace (ASO EVO, Medical Specialties, Inc., Charlotte, NC). The support was a lace-up brace with nylon straps that wrapped around the calcaneus. It also has an elastic cuff that wraps around the front of the brace.[12] The running shoe used in the investigation was the individual participants own footwear which were traditional in the construction and cushioning across the midsole. The high-cut basketball shoe (Converse basketball shoes, high top, A100086CV) was the same for all participants and possessed a rigid sole with limited cushioning relative to the running shoes.

Participants wore markers on the right leg which was their dominant leg that supported them during the cutting movement. These markers were positioned using a modified Helen Hayes model as described by Kadaba et al.[29] Markers were positioned on the right and left asis, sacrum, right thigh, right medial and lateral knee, right shin, right medial and lateral ankle, and the top of the foot and on the calcaneus which were placed directly onto the shoe. Markers placed onto the shoe have been shown to represent similar but not identical movement of the foot.[30] Whilst studies have found over and under-estimations of the movement of the foot,[31,32] the difference in movement that occurs is systematic and can be used to represent relative movement of the foot for different conditions,[30] albeit with caution when making clinical interpretation based on values obtained.[32]

Participants were required to run in a straight line for 5.5 meters and at an angle of 45º identified via markings on the floor. Once they reached a force plate, they placed there foot and pushed off at the 45º angle identified on the floor; they then continued their run. Approach speed was standardised at 4.5 m/s which was controlled via a set of electronic timing gates (Speed

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trap 2, Brower Timing Systems, Draper, UT, USA). Any trial that was not at the speed (± 5 %) was subsequently repeated.

Each participant performed 10 cutting movements in each of the three footwear conditions in a counterbalanced order. The movement was recorded via an 8 camera motion analysis system (250 Hz, Cortex, Eagle Digital Real Time Camera System, Motion Analysis, Santa Rosa, CA, USA) synchronised with a force plate (2000Hz, 9287BA, Kistler Instrumented AG, Winterthur, Poland). The kinematic data was processed within the motion analysis software and smoothed using a 4th order, zero lag, low-pass Butterworth filter with a cut-off frequency of 6 Hz as used in other similar research[8] and is optimal for low velocity movements such as those used in the current investigation.[33]

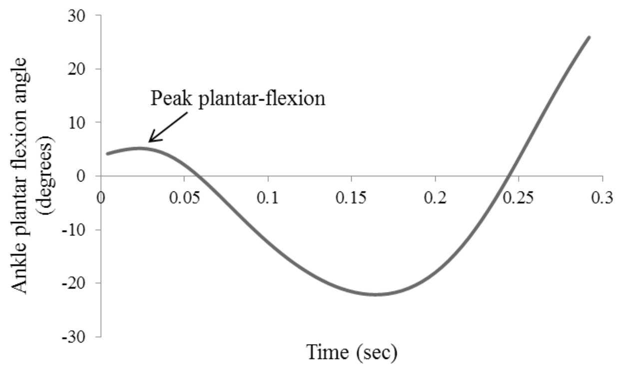

Figure 1: Typical angle-time history for ankle plantar-flexion and dorsi-flexion during a cutting movement for a single participant. Peak plantar flexion identified.

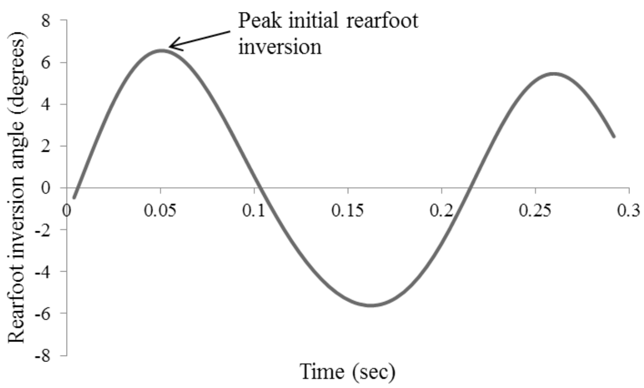

Figure 2: Typical angle-time history for rearfoot inversion and eversion during a cutting movementfor a single participant. Peak initial rearfoot inversion identified.

Angle-time profiles were calculated for the inversion-eversion and plantar-flexion-dorsi-flexion movement and referenced to a neutral standing position to remove differences in marker placement that influence the comparison of the independent variable. The dependent variables were identified from the angle-time profiles and included plantar-flexion (Figure 1) and peak initial rearfoot inversion (Figure 2); peak impact force was identified from the force plate data as the first peak occurring within the first 50 milliseconds[34] and was reported in bodyweights. The mean of the 10 trials per condition were calculated and statistically compared using SPSS (IBM SPSS 21, New York, NY, USA). Normal distribution of the data was shown and an ANOVA with repeated measures were performed for each dependent variable. Statistical significance was accepted at alpha level < 0.05. Partial η^2 effect sizes and F values were reported for all comparisons. The effect sizes were interpreted based on the relationship between the percentage of variance explained and Cohen's d as published by Cohen.[35] Pairwise comparisons with Bonferroni corrections were used to identify the location of any significant differences between footwear conditions.

RESULTS

Statistical analysis of the kinematic data collected during the "v"-cut manoeuvre indicated that plantar-flexion was not significantly different ($F = 2.94$, $p > 0.05$) despite a trend towards a large difference between the footwear conditions (Partial $\eta^2 = 0.25$). On the other hand, peak initial rearfoot inversion was significantly different between the footwear conditions ($F = 33.36$, $p < 0.05$, Partial $\eta^2 = 0.788$). Post-hoc tests demonstrated that significantly larger rearfoot inversion values were shown for the high-cut high top compared to both the low-cut running shoe ($p = 0.001$) and the low-cut running shoe with brace condition ($p = 0.001$). There was no significant difference between the running shoe and running shoe with brace condition ($p = 0.30$).

	Low-cut running shoe	Low-cut running shoe with brace	High-cut basket-ball shoe
Peak plantar flexion (deg)	3.4 ± 7.5	2.4 ± 7.4	6.4 ± 8.4
Peak initial rearfoot inversion(deg) *	-0.2 ± 2.9	1.7 ± 3.4	9.1 ± 3.6
Peak impact forces (BW)	2.6 ± 0.4	2.6 ± 0.5	2.8 ± 0.5

* denotes a statistically significant difference

Table 1: Mean and standard deviations of peak plantar flexion and initial rearfoot inversion angles (degrees) as wellas peak impact forces (bodyweights) collected during cutting in the low-cut running shoe, low-cut running shoe with brace and high-cut basketball shoe conditions.

A comparison was also made between footwear conditions for the measurement of peak impact force. Analysis indicated that there were no significant differences between the three footwear conditions for this variable ($F = 3.189$, $p > 0.05$, Partial $\eta^2 = 0.26$) (Table 1).

DISCUSSION

The current investigation sought to understand how the kinematics of performing a 45° cutting movement in traditional high-cut basketball shoes differs to wearing a low-cut running shoe or low-cut running shoes with ankle brace conditions. In agreement with the study hypothesis, it was shown that the addition of an ankle brace reduced the ankle rearfoot inversion measurement which is associated with lower incidence of ankle pain.[36] This finding also supports the evidence that prophylactic ankle supports can reduce the risk of injury through reduced inversion[11,12,23] in comparison to high-top basketball shoes.[25]

In contrast to the study hypothesis, the low-cut running shoe without the ankle brace had reduced peak initial rearfoot inversion compared to that experienced with the high-cut shoe and had similar values to the brace condition. Such finding is contradictory to the traditional view that improved stability is provided by high-cut shoes and that running shoes are more unstable since the midsole cushioning allows for increased compression on the lateral edge, which increases the external torque and introduces greater instability.[8] The finding is also contrary to biomechanical studies that have shown increased levels of mechanical support in high cut shoes.[9,18,19,37,38] It does however support findings from Gottschalk & Pepple,[24] and Rovere et al.[25] that high-cut shoes do not offer any advantage to low-cut shoes when protecting the ankle to excessive inversion. It is possible that the differences in results may relate to differences in task being performed and the size of the load being forced onto the ankle. Further still, the increase in ankle inversion in basketball shoe was not accompanied by a significant increase in plantar flexion in either the comparison of low-cut shoe or low-cut shoe with ankle brace. This therefore demonstrates that plantar flexion did not contribute to the increased inversion as described in the hypothesis.

A possible reason for the finding that greater support was provided by the running shoe alone condition is that co-activation of the antagonistic muscle groups was occurring prior to and during the early stance phase to help stabilize the ankle and foot.[39,40] This is an important factor influencing dynamic joint stability to protect the lateral ankle ligaments from excessive inversion due the experience of rapid loading.[39,40] Such activation may have stiffened the joint so that it barely experienced inversion which is represented by the slight everted magnitude experienced at the rearfoot.

With stabilisation of the ankle joint, increased activity of gamma motor neuron and a decreased reaction time has been demonstrated.[40,41,42] However, Hopkins et al.[41] questioned whether the peroneal muscles and the stiffness provided by the contraction would be sufficient to provide stability to the joint during tasks that were more dynamic. The antagonistic muscle activation may therefore not be rapid enough to control the movement during faster movements, contributing to greater risk of injury in the low-cut footwear. Similarly, had fatigue occurred similar to that in a game situation or in a situation where the participants could not predict the turn, this protection strategy may have also diminish and rearfoot inversion may increase due to a delay in the activation.

Another view on the muscular control and the protection provided may be given in the work of Fu and Colleagues[9] who found that during a jump landing task, there were no significant differences between the various types of shoes of varying ankle height in the maximum ankle inversion angle. Simultaneously collected EMG data showed that wearing high-top shoes can, in certain conditions, induce a delayed pre-activation timing and decreased amplitude of evertor muscle activity resulting in increased inversion. Therefore, in the current investigation, the increased inversion in the high-cut footwear may relate to this delay in timing of the muscle contraction.

An alternative interpretation of the results could be that the greater rearfoot inversion demonstrated with the high-cut basketball shoes resulted as a mechanism to aid impact attenuation for its harder midsole.[7,36] Stacoff et al.[34] found that during lateral movements, maximum rearfoot inversion occurred within the first 50 milliseconds after touch-down, which is approximately the same time span that the maximum magnitude of pronation occurs during running which is used as a shock absorber during impact. This explanation is supported by the similar impact force across footwear conditions despite suggested differences in cushioning and is consistent with the literature.[43,44,45] Additional plantar flexion can also serve as a method to reduce impact force during lateral movements,[18] although there was no statistical evidence of this in the current investigation. The study therefore provides no support to the thought that peak impact force and possible lower extremity loading was lower with the cushioned footwear compared to the high-cut basketball shoe.

As ankle injuries are often cause by an acute event, interpretation of biomechanical studies investigating ankle injury are often limited since the conditions do not replicate exactly the conditions for injury. Often greater traction, approach velocity, unpredictable turning conditions or fatigue will occur in addition to differences in footwear which contribute to cause ankle movement in excess to that observed in the current investigation. Various studies (e.g.[46,47,48]) have also highlighted the interactive effect of the footwear with the surface and the importance of the playing surface combination when discussing the effect of playing shoes. As the current study performed the cutting manoeuvre directly onto a force plate, surface conditions were un-representative of normal playing conditions. It would therefore be important that future investigations consider the playing surface more closely, as well as the approach velocity, unanticipated turning conditions and fatigue, to understand how these factors would influence the response to the footwear condition.

CONCLUSION

In conclusion, based on the findings of the current investigation, high-cut basketball shoes do not offer the support to rearfoot inversion that is traditionally thought. The evidence that reduced rearfoot inversion is found with running shoes with and without ankle bracing also supports injury rates discussed in the literature. Consequently, it appears that healthy, uninjured amateur basketball players can utilise running shoes and perform cutting movements without increasing initial rearfoot inversion or the potential risk of injury compared to traditional high-cut footwear. Caution is needed however since the effect of other risk factors such as the playing surface, fatigue and

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movements is unknown. As the brace supports the ankle mechanically, there may be different mechanisms behind the similar inversion magnitudes demonstrated in the study. Consequently, it may be beneficial to wear the brace with the low-cut running shoe given the factors that could influence the activation of the supporting ankle musculature that were proposed as protecting against the increased inversion.

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